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U. S. Naval Submarine Base
New London

A SURVEY OF METHODS USED IN ADMINISTERING PSEUDO-ISOCHROMATIC TEST PLATES FOR COLOR VISION

Color Vision Report No. 3

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SUMMARY

Routine testing of the color vision of applicants for Submarine Service by the Medical Research Laboratory, New London, revealed that previous physical examinations had been only 50% effective in screening out color defectives by the criterion of the test itself.

The object of this investigation was to find the errors in administration of the pseudo-isochromatic plates which had contributed to the unreliability of the previous tests. The data were obtained by interview with 27 applicants who had passed their physical examinations for Submarine Service but failed a brief, properly administered screening test for color vision at the Submarine Base.

Previous tests were found to have been badly conducted and loosely interpreted. The principal faults were found to be:

I. Incompetent and careless administration of the plates:

1. Non-standard illumination.
2. Uncontrolled conditions of presentation.
3. Too few plates shown.
4. Reading aids permitted.

II. Widely variable interpretations of a passing score:

1. At the examiner's discretion.
2. According to different Navy directives.

The adoption of the Bureau of Standards proposal of April 1943 would correct most of the above faults of administration and interpretation.

A report on the effects of illumination on laboratory color tests is in preparation and field tests are being run to determine color vision requirements for Submarine Service.

As generally administered and interpreted in the Navy the A.O. test is concluded to be unreliable and largely ineffective as a test for color vision.

PROBLEM

From May 24 to August 14, 2561 men were examined for Submarine School by the Medical Research Laboratory of the Submarine Base. Each man had had from one to five physical examinations previous to his appearance at the laboratory yet 105 or approximately 4% of the applicants were found to be defective in color perception. They were detected by the routine presentation of 8 A.O. Co. pseudo-isochromatic plates (numbers 17 to 24 inclusive). Since 4% is half the incidence of color anomaly usually reported from a normal U.S. male population by this type of test it appears that not over half of the Naval applicants with color defects are eliminated by routine examinations.

While all degrees of color anomaly except the mildest are represented in this sample, the severity of defect of many men was such as to render them obviously unfit for submarine duty as determined by other tests. None of the 105 applicants were "normal by the Stiiling tests" or its equivalent, as provided in the Manual of the Medical Department of the Navy which directs that the preliminary examination for submarine service shall be given with "particular care." This raises the question: What are the reasons that so many color defectives are being passed for submarine examination?

On the other hand it is well known that a slight deficiency in color perception has been made the cause for the rejection of otherwise able-men. The files of the Color Vision Laboratory at New York University contained detailed records of such rejections. Normal observers frequently make minor errors not related to color deficiency. This situation was noted in the BuMed directive of September 25, 1942, which advised that "medical examiners exercise sound judgment in evaluating errors in reading the plates..." Therefore, from the standpoints both of acceptance and of rejection the evidence indicates that color vision exams are, with reliability, neither eliminating the unfit nor passing the fit.

PROCEDURE

Test Sample:

Of the 105 color defectives detected in the course of routine examinations, 27 were selected at random for interview and more thorough testing. These 27 reported on a total of 63 previous physical examinations conducted at 51 ships and stations. This sample is considered to be large enough to indicate the variety of factors which result in acceptances.

All of the men in the sample were definitely "color blind" as tested by the abridged A. O. Plates and by some or all of the following tests:

Dimmick-type Anomaloscope, Rabkin Polychromatic Plates, F-M 100-hue Panel, Dichotomous Panel, Royal Canadian Color Vision Lantern, Edridge-Green Lantern, and the I-S C.C. Color-Blindness Test (Navy Model). The abridged A. O. is a selection of 18 plates with high diagnostic value which has been recommended to the Surgeon General for adoption. It has been shown by the Bureau of Standards and at Randolph Field that an abridged version could be made which would give a more definite differentiation between degrees of color anomaly than does the complete book. Scores in the test group ranged from 100% error to 44% error; 28% is a failing score according to the interpretation accompanying the proposed abridgement.

Interviews:

Interviews were conducted informally after the routine examinations were completed so the men could be assured that their statements would not affect their records. Previous examining situations were recalled by asking questions such as, "What kind of day was it?" "Was it a pleasant room?" "Big, little?" "Where were you standing?" "What did you see when you looked out the window?" "Who held the book?" From such conversation most of the specific factors reported in the Appendix could be secured without direct questions which might have biased the answers. The weaknesses of the interview technique were recognized and subsidiary checks were made by examination of service records, by correspondence and by personal visits to the stations.

ANALYSIS OF APPARENT REASONS FOR ACCEPTANCE

Detailed information on test conditions as obtained from the interviews is tabulated for the reader's reference in Appendix A. The information which apparently accounts for or directly bears on the applicant's acceptance is summarized under 5 headings: Malingering, Procedure, Conduction, Standards and Illumination. When several factors could have influenced an acceptance all are recorded in the tabulations.

Malingering:

The 4 cases of malingering are not of interest in this study except as better test administration would eliminate the more common forms. Applicants No. 15 and 22 depended upon the coöperation of other men in the group. They could have succeeded with their methods only in group testing. No. 3 was coached by a friend who regularly administered the test for another arm of the Services, and hence had access to the plates. An increasing number of men are found who have memorized the plates under the guise of "color therapy" or "vitamin treatments" but none happened to be included in this study.

General Procedure:

7 acceptances are attributable to methods or errors in general procedure. In 5 instances no color test was given with the physical, including the case of a man who was transferred from a restricted to an active status without re-examination. One of the two remaining examples is the unusual case of a man who passed at the recruiting office with the expectation that he would be rejected at the enlistment station, where it happened that the color test was not given. The other case is one in which the man continued to be retained or re-enlisted with no further action taken even when retests indicated color-blindness. In various degrees this situation probably occurs more often than the tabulation indicates.

Conduction of Tests:

Excluding the above men there remain 52 records in which "color-blind" men took tests fairly and were passed for unrestricted naval duty. 32 of these cases can be ir-

terpreted from the interview data as resulting, at least in part, from faults in the methods of conducting the tests; either too few plates were shown or the men were somehow aided in reading the plates. These cases are classified in Table I. There are 23 reports of a "few" or of less than a dozen plates presented for response. The A.O. Test includes so many plates of little or no diagnostic significance that 8 or 12 plates selected at random might not constitute an adequate test.

It is known that close presentation is a considerable aid to recognition by some color-deficients. Certain stations present their plates on a shelf which brings them to within a few inches of the observer's eyes. Some observers were permitted to hold and manipulate the book so they were in a position to inspect the figures at close range. Tracing of numbers was permitted at least three times and probably much oftener for tracing is a semi-conscious action not likely to be remembered for report. Various freedoms of presentation were permitted up to the case in which the M. D. gave the book to the applicant and said, "Walk around the room until you find a light or position where you can see the numbers". One man was frankly coached by an examiner and, in a number of cases too indefinite for tabulation, friendly examiners helped with suggestions as to what the numbers might be, or indicated when the first responses were wrong. In the larger recruiting stations it seems to be the custom for the examiner to walk down a line of men with an open book. This permits every testee to hear responses which are willfully or unconsciously a considerable aid to recognition.

Cautions against permitting all of the above non-standard practices are contained in the Bureau of Standards proposal of April 1943 for the abridgement and standardization of administration of the A. O. plates. These recommendations were drawn by Dr. Deane B. Judd, physicist, after extensive consultations, upon the request of Lieut. A.P. Webster of the Bureau of Medicine and Surgery. Practically all of the above evils in administration would be eliminated if these suggestions were adopted and observed.

Standards of Acceptance:

Various criteria of "passing" and "failing" have been observed, proposed and officially adopted by the Navy in recent years. Only a liberal interpretation of the standards would have passed the men in the 21 tests itemized in Table II. 8 of these were passed without comment on the health record in spite of failure to read correctly some proportion of the plates presented. 11 acceptances were accompanied with qualifying phrases preceded by "defect noted". Two fairly severe cases were passed on the ability of the men to see at least one each of the three color groups as directed in the Bulletin of Medicine and Surgery of Sept. 25, 1942. If this directive were taken literally, it would exclude very few applicants. It does not, however, apply to preliminary examinations for Submarine Service nor can it be used to explain the passing of men who were shown but one or two double pages of the A.O. book. One man was accepted on the basis of his ability to pass the Navy Wools (Holmgren type). Another's acceptance was influenced by his ability to name the colors of the dots.

Altogether, Table II indicates that the criterion of "passing" was very low for at least 21 acceptances. This is not intended as a criticism for it is not the purpose of this report to examine the critical level of acceptance. The condition that is made evident is the uncertainty of the standards and irregularity with which they are applied.

Illumination:

After the report on the 58 color examinations has been thoroughly fine-combed there remain a number of cases entirely unaccounted for by malingering, procedure, conduction and standards; and the reported test scores are in general inexplicably high as compared with the individual's performance at the New London Laboratory where standard lighting is employed. The directions accompanying the Stilling, Ishihara and the A.O. emphasize the importance of "daylight illumination". The Ishihara Manual states that "...it is essential that the test for color-blindness should be conducted in a light room in the daytime". Stilling - "The test is carried out in daylight". A.O. Co. - "The illumination should be diffused daylight".

Examination of Table III shows that out of 58 color vision examinations*, only 17 or 29% were reportedly given by window illumination alone, 10 by window and incandescent together and 24 by incandescent alone. 10 of the 12 "unexplained" examinations were given under non-standard illumination. Experimentation has shown that yellow illumination improves the response scores of all Deuteranomalous ("green blind") and of mild Protanomalous ("red blind") Observers and it may be fairly assumed that faulty lighting was responsible not only for the passing of the "unexplained" men but was of assistance to an unknown extent in more than half the 58 examinations.

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* It will be remembered that for 5 men no test for color vision was included in the physical examination.

CONCLUSION

As generally administered and interpreted tests with A.O. plates are concluded to be unreliable and more than 50% ineffective in screening color defectives.

Indications are that the largest contributing factor is improper lighting of the plates; that other factors in descending frequency of report are: ambiguous and variable standards of what constitutes success or failure; inadequate number of plates shown to the examinee; free presentation of plates including such observational aids as tracing, close viewing, and viewing at an angle; omission of color test from the physical examination and, least often reported, coaching by the examiner and procedures which permit malingering by the examinee.

Screening tests should be administered according to the Bureau of Standards recommendations.

No conclusion is drawn concerning the value of the test material itself, the proper interpretation of scores or the degree of color normalcy required for various branches of Naval services. These questions require further research.

Proper illumination appears to be of paramount importance and will consequently be made the subject of a special report. Field tests are under way to determine what correlation can be found between Submarine Service requirements and other color vision tests.

TABLE I

Analysis of 32 Acceptances Apparently Influenced by Improper Conduction of Tests (excluding methods which permit malingering).

	No. of Cases
12 or less plates shown, also reported as a "few" "less than three pages", "a couple of pages".....	23
6 or less plates shown	9
Free Presentation. Total of tests in which reading aids were permitted	18
Book close to eyes (est. less than 18 in.)	10
Indefinite time allowed	7
Applicant permitted to hold book	5
Tracing permitted	3
Coaching by the examiner (specifically admitted)..	2

Several types of improper conduction were reported in some test situations and are itemized separately. Therefore, a considerable overlap is apparent in the totals for it is impossible to say which condition had the greatest weight, or if the final effect was merely a summation of several contributing factors.

TABLE II

Analysis of 21 "Passed" Tests Apparently Influenced by Low Standards of Acceptance

(1) Case No.	(2) % Plates Failed at New London	(3) No. Plates Failed in a Previous Test	
		Passed Without Comment .....Total 8	
11	89	Few	
18	67	½ dozen	
19	67	2 of few	
23	61	Some	
		Few	
27	44	Many	
		Some	
		Some	
		Passed With Comment as Noted..... Total..... 11	
2	89	Some	"Color perception slow"
3	89	Most	"Read some basic plates"
5	61	15	"Sufficient for general service"
8	95	Many	"Partially color-blind"
9	89	Some	"Color perception fair"
10	89	Some	"Bad A.O.C...reads 1 in each of 3 groups"
18	67	?	"Color perception good"
20	61	Some	"Color weak"
22	61	1 of 3	"Defect noted"
23	61	Many	"Color deficient"
		Passed on Basis Other than Reading of Figures.....Total 2	
1	95	Some	"Named color of dots in A.O. plates"
26	50	Some	"Passed Navy wool test"

Column (1) gives the applicants' case number as found in the Appendix. Column (2) refers to the abridged A. O. Test administered under standard conditions. Column (3) gives the number of plates failed as reported by the Subject in interview.

TABLE III

Report of Illumination Used in Testing 27 Men in a Total of 58 Examinations for Color Perception

Illumination	Number of Tests	
Natural window daylight	17	
Incandescent "daylite" fixture (Illuminant C)	0	
Total Number of Tests Given Under Standard Illumination*		17
Incandescent and natural daylight together	10	
Incandescent alone	27	
Fluorescent alone	1	
Fluorescent with daylight	1	
Total Number of Tests Given Under Non-Standard Illumination		39
Illumination Unknown		2

*It is not actually presumed that all these cases represent standard illumination. The color temperature of skylight commonly ranges from 6000° K to 15000° K and this may be seriously modified by reflection from objects outside the window.

Notes to Accompany Appendix A

The 6 protanomalous ("red-blind") applicants are followed by 21 deuteranomalous ("green-blind") applicants. The applicant's case-number is given in column 1, his initials in column 2, his rank or rate at the time of applying for Submarine School in column 3. Each group is arranged in descending order of the number of errors which they made on the abridged set of 18 A.O. plates administered under standard conditions. While this order indicates the relative difficulty which they have with pseudo-isochromatic tests it does not necessarily indicate their relative degree of color deficiency.

"X" 's in columns 5, 6 and 7 show, to the best of the applicant's recollection, what the illumination was. Since a large variation in color of illumination will pass unnoticed, column 7 is probably quite incomplete.

Columns 8, 9, 10 and 11, indicate situations in which some factors of free or uncontrolled presentations were present. An "X" in column 8 indicates that the applicant was permitted to view the plates at a short distance presumably close enough for eye tracing. An "X" in column 9 indicates cases in which the applicant was permitted to hold the book of plates, with such attendant advantages as viewing at an angle and changing the light effects. An "X" in column 10 indicates that the applicant was given "plenty of time", "all the time I needed", or indicated that the examiner "let me study them". Other aids include: practice from repeated exams, coaching, tracing, naming the colors of the dots and that subconscious influence which comes from hearing men ahead in line call the numbers. Only one man mentioned this situation (aside from those who deliberately connived) but the influence is doubtless considerable in large receiving stations.

In column 12 is listed the applicant's recollection or estimate of the number of plates presented for response, an item for which the memory is often sharp. The response of "a few" was carefully questioned and was used if determined to be less than three double pages; otherwise the designation was changed to "some". Column 13 lists to the best of the applicant's knowledge, the number of plates incorrectly called. This is probably an unreliable column since many examiners do not customarily give applicants positive knowledge of test results.

Deliberate malingering is reported by 2 applicants on 4 occasions in column 14. When no test for color vision was included in the physical examination, this is shown in column 15. The number of times the applicant had been rejected on the grounds of deficient color vision previous to his acceptance in the Navy is shown in column 16.

Column 17, in addition to notes to which reference is made by symbol in previous columns, contains the reasons ascribed for acceptance of the applicant so far as these reasons were available.

APPENDIX A

Summary of Interview Reports from 27 Color Anomalous Applicants

Number	Applicant	Rate or Rank	Date of Exam	Illum. Window	Illum. Incandescent	Illum. Other	Aids Close to Pls.	Aids Supp. held Pls.	Aids Time allowed	Aids Other aids	Number of Plates Presented	Number of Plates Missed	Malingering	No test given	Previous rejts.	Notes, including reason for acceptance.
1.	JAK	S2c	7/42		X		X		X	*	Lost	Some			2	*Tracing permitted, named color of dots.
			4/43	X	X						Few	0*				*"Happened to be some I knew."
2.	JZH	Ltjg	6/38	X							Lost	Some				Passed as "slow".
		*	39/41	3							Few	?				*6-12 No. re-exams, same conditions
3.	MG	M2c	1/41	X							Most	Most	X		1	Studied nos. by tracing. "Some
			2/41		X		X	X			3	0*				basic plates."*"Very easy plates."
4.	LBZ	S2c	6/42	X		*			X		Few	0**				**"Easy numbers." *Flucrescent.
			7/42 6/43	X						*	3-4	0		X		*Heard men ahead call numbers.
5.	LM.	Mo1. 2c	6/43		X						All	15+			2	"Sufficient for regular navy."
			2/43			*					4	0**			2	**"They were 4 plates I could read." *Fluorescent.
6.	JHD	F1c	5/42		X						All	?				No comment.
			5/42		X		X		X		All	?				No comment.
7.											Deuteranomalous Observers					
7.	RHC	S2c	2/43		X	*	X		X		6-8	*				*Opal bowls, "had a little difficulty." *He said I was "all right"
			3/43		X		X		X		4	*				
8.	SDB	S1c	6/42	X	X	*					All	Lost			3	*Failed both ways; "given a chance"
			6/42											X		

Number 1	Applicant 2	Rate or Rank 3	Date of Exam. 4	Illum. Window 5	Illum. Incandescent 6	Illum. Other 7	Aids: Close to Pls. 8	Aids: App. held Pls. 9	Aids: Time allowed 10	Aids: Other Aids 11	Number of Plates Presented 12	Number of Plates Missed 13	Malingering 14	No test given 15	Previous rejts. 16	Notes, including reason for acceptance.
9.	PAA	M2c	1/42	X					X		Half	Some				Noted as "color perception fair."
10.	LHP	M2c	3/42	X	X						6-8	Some				"Bad AOC...reads 1 in each of 3 groups."
			4/42	X	X		X	X	X		Some	Some				"Color perception - slow."
			9/42											X		
11.	ACC	Flc	9/42		X						All	Few				"PhM wasn't sure; M.D. OK'd me."
12.	INL	Enl.	7/37		X						Few	1				
			11/42	X							5-6	0				
			5/43		X		X				All	1†				No comment.
13.	CRC	S2c	3/43	X							3	0			2	Not asked to read 4th Pl.("I couldn't").
			3/43	?	?						* Half	Most				*"Dr. told me the hard ones--then I could see them."
14.	WJC	FC3c	4/42		X						Most	Many			1	Classified V-1 SP, defective C.V.
			1/43											X		Assigned to active duty.
			7/43		O									X		Reported for sea duty.
15.	PAK	M3c	11/42	X	X						4	0*	X			*"Asked men ahead in line to call numbers loudly."
16.	LB	F2c	1/43		X		X				* 6-12	1				Indicated numbers with finger.
			6/43	?	?						4-6	?				No comment.
17.	FE	Flc	1/43		X		X				* Many	?				'Passed'. Had brush in hand.
			2/43	X	X	*					Many	?				*-Yellow brick buildings outside.
18.	F H	Flc	12/42		X						Half	?				'Passed'. "Color vision good."

Number 1	Applicant 2	Rate or Rank 3	Date of Exam. 4	Window 5	Incandescent 6	Other 7	Close to Pls. 8	App. held Pls. 9	Time Allowed 10	Other Aids 11	Presented 12	Missed 13	Malingering 14	No test given 15	Previous rejts. 16	
19.	GCH	Ens.	11/38		X						8-9	0				
			11/42	X	X						Few	2				"M.D. said it wasn't serious."
			4/43		X						Part	Few				"Hesitated - slow - got most right."
20.	RJB	S2c	2/43		X						8-12	Some				"Passed as color-weak."
21.	EBH	BM2c	8/43	X	X		X	X			Many	*				*"Missed some of first 4 plates."
22.	AEC	S2c	11/42	X							3	1				Passed with "defect" noted.
			11/42	X							Few	2	X			"Buddies tapped out plate no. on ribs."
			11/42	X							Few	2	X			"Buddies tapped out plate no. on ribs."
23.	JSH	Ens.	6/42	X			X	X			Most	Many				1 Accepted, noted, "color deficient."
			7/42	X	X		X				Most	*				Failed test; accepted.
			7/42		X						Many	Some				"Passed".
			9/42		X						Most	Few				"Passed".
24.	DB	S2c	11/42		X						Few	0				No comment.
			2/43		X						Few	1				No comment.
25.	RVH	RT1c	9/42		X		X				All*	*				Repeated:1st, many errors; 2nd, good.
26.	FVD	Y3c	9/42	X	X						All	Some				Passed wools.
				X		*					All	2†				*Wing of red brick building outside.
27.	RKH	Lt.	7/40	X							Half*	Some				*Repeated, no comment.
			40-41	2							All	Many				2 tests in dispensary.
			42-3		3					*	Most	Some				3 tests on tenders, "went over figures."